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Productivity, competition indices and soil fertility changes of *Bt* cotton (*Gossypium hirsutum*) – groundnut (*Arachis hypogaea*) intercropping system using different fertility levels

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ABSTRACT

A field experiment was conducted during rainy (*kharif*) seasons of 2006 and 2007 to study the productivity, biological feasibility, economic viability and nutrient dynamics in *Bt* cotton (*Gossypium hirsutum* L.) - groundnut (*Arachis hypogaea* L.) intercropping system under various fertility levels. Groundnut as an intercrop enhanced the productivity of cotton by 0.25 tonne/ha. Cotton receiving no N showed superior performance of intercropped groundnut in terms of pods/plant (36.0), kernels/ pod (1.56) and pod yield (0.56 tonne/ha). The mean N, P, K uptake in intercropped cotton were 79.4, 6.6, and 46.0 kg/ha higher than sole cotton (149.9, 16.3 and 80.0 kg/ ha), respectively. Among N management practices, substitution of 25% RDN through farmyard manure in cotton gave the highest system productivity (3.5 tonnes seed cotton equivalent yield/ha), net returns (₹50 780) and production efficiency (19.4 kg/ha/day). The highest B: C ratio (2.58) was observed with 100% RDN, followed by 75% RDN + 25% through FYM (2.29). Control treatment gave the highest LER (1.72), RNR (1.37) and ATER (1.47), followed by 50% RDN + 50% through FYM. However, soil NPK balance were in favour of 50% RDN substitution through farmyard manure.

Key words: *Bt* cotton, Competition functions, Fertility, Groundnut, Nutrient uptake, Yield

Cotton (*Gossypium hirsutum* L.) cultivation in India covers an area of approximately 9.4 million ha representing about one quarter of the global area of 33 million ha under cotton (FAO 2007). Cotton is planted by four million small farmers and involves many more in processing, textile manufacture and trade. However, the average yield of cotton lint, 462 kg/ha, is far below the world average of 736 kg/ha and the production is only about 18% (4.3 million tonnes) of the world production of 24.3 million tonnes. Main losses in cotton production are due to its susceptibility to about 162 species of insect pests and a number of diseases. Among the insects, cotton bollworms are the most serious pests of cotton in India causing annual losses of at least US$300 million. Insecticides valued at US$660 million are used annually on all crops in India, of which more than half are used on cotton (Manjunath 2004). Further, the most destructive pest, *Helicoverpa armigera* is known to have developed resistance against most of the recommended insecticides, forcing farmers to apply as many as 10–16 sprays. The transgenic cotton era has dawned in our country with the approval accorded by GEAC (Genetic Engineering Approval Committee), Government of India for the commercial cultivation of *Bt* cotton hybrids in the southern and central zones from 2002 crop season onwards. *Cry 1 Ac* gene of *Bacillus thruriengensis* (a soil-borne bacterium) which has the capacity to produce proteins (end toxins) toxic to lepidopteron pests in general, has been introduced in cotton, conferring inbuilt resistance (Venugopalan *et al*. 2009). These *Bt* cottons not only give higher yields, but also higher net income over traditional cottons due to reduced plant protection costs. In 2008, transgenic cottons have been estimated to be cultivated in 7.6 million ha in India as per the annual review report of the US based International Service for the Acquisition of Agri-Biotech Application (ISAAA 2008). Among all the approaches of increasing the agricultural productivity, intercropping is one of the highly promising possibilities. Cotton is sown at wider row spacing, hence provides space for cultivation of short-duration intercrop like groundnut. This practice stabilizes the productivity, besides enhancing the total returns (Singh *et al*. 2009). Among the agronomic packages of any crop, nitrogen management is the most important factor deciding

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the crop performance and maintaining soil fertility is important in sustaining cotton productivity and profitability. Although the use of chemical fertilizers is the fastest way of counteracting the pace of nitrogen depletion. From technical, economical, logistical and environmental consideration, the best course is to practice integrated nitrogen management (INM). Looking to the prospects of large area coming under *Bt* cotton cultivation and shrinkage of land holdings of cotton farmers in the next few years, the present experiment was undertaken with the objectives to assess the yield advantage by including groundnut with *Bt* cotton, soil fertility changes and the biological and economical feasibility of the crop to developing appropriate production packages for northern Indian conditions.

MATERIALS AND METHODS

Field experiments were conducted in sandy loam soil with *p*H 7.8 and 8.1 (1:2.5 soil to water) containing 0.42 and 0.46% organic carbon, 227 and 207 kg/ha available N, 12.8 and 13.6 kg/ha available P, and 270 and 282 kg/ha available K in the 0–30 cm soil layer between 2006 and 2007, respectively in research farm of Indian Agricultural Research Institute, New Delhi. The total rainfall received during the cropping period was 629.5 mm in 2006–07 and 489.0 mm in 2007–08. The (9) treatments comprising combination of two cropping systems (sole cotton and cotton + groundnut) and four fertility levels (control, 100% recommended dose of N (RDN), 75% RDN + 25% N (through FYM) and 50% RDN + 50% N (through FYM) to cotton along with sole groundnut (with recommended N and P) were laid out in a randomized block design with three replications. In cotton, 150 kg N/ ha was used as RDN. Well decomposed farmyard manure (FYM) was uniformly incorporated into the soil seven days before sowing as per treatments. FYM on dry weight basis contained 0.5–0.2–0.5% N-P-K, respectively. The quantity of P and K being variable owing differential quantities of FYM addition was not balanced. As per treatment 50% N each through urea was applied at sowing and square initiation stage. A uniform dose of 26 kg P/ha through single super phosphate (SSP) was applied at sowing. Cotton 'RCH 134 *Bt*' was sown by dibbling with 120 cm × 60 cm geometry on 17 June in 2006 and on 2 June in 2007. In sole groundnut 'Punjab Groundnut 1' was in rows 30 cm apart using a seed rate of 100 kg/ha. In intercropped cotton, three rows of groundnut were planted in between cotton rows. Groundnut was harvested in last week of October. Cotton was harvested in two pickings up to last week of November. For assessing the biological feasibility and economic viability of the system, land use and production efficiencies were computed as suggested by Ahlawat *et al.* (2005).

RESULTS AND DISCUSSION

Bt cotton

Intercropped cotton showed higher growth and yield

Table 1 Growth, yield components and yield of sole and intercrop cotton and groundnut as influenced by cropping systems and fertility levels (pooled data of 2006 and 2007)

Treatment	Cotton							Groundnut						
	Plant height at 150 DAS (cm)	Dry matter production at 150 DAS (g/plant)	Number of main stem nodes/ plant at 150 DAS	Opened bolls/ plant	Boll weight (g/boll)	Yield (tonnes/ha) Seed cotton	Stalk	Plant height at harvest (cm)	Dry matter production at harvest (g/plant)	Pods/ plant	Kernels/ pod	1000-kernel weight (g)	Yield (tonnes/ha) Pod	Haulm
Cropping system														
Sole cotton	128.8	530.0	20.6	42.7	4.0	2.6	4.6							
Sole groundnut								53.1	149.6	91.5	1.68	278.1	1.06	3.25
Cotton + groundnut (1:3)	130.0	545.0	21.3	44.1	4.1	2.8	4.9	65.5	69.4	30.4	1.48	254.8	0.47	1.81
CD (*P*=0.05)	NS	NS	NS	NS	NS	NS	NS	5.89	10.01	4.82	0.047	12.21	0.072	0.232
Fertility level														
Control	111.3	370.4	18.4	31.3	3.6	1.8	4.1	58.7	88.0	36.0	1.56	261.0	0.56	2.12
100% RDN	128.9	549.5	20.9	44.6	4.1	3.1	4.9	68.7	63.2	26.7	1.46	254.8	0.43	1.67
75% RDN + 25% through FYM	145.7	674.3	23.6	52.9	4.6	3.2	5.6	72.5	51.6	24.8	1.41	248.2	0.41	1.54
50% RDN + 50% through FYM	131.7	555.6	20.6	44.7	4.0	2.7	4.7	62.3	75.1	31.5	1.52	255.3	0.48	1.92
CD (*P*=0.05)	9.22	56.49	2.01	3.98	0.30	0.26	0.38	3.76	12.52	6.12	0.061	NS	0.096	0.294

attributes over sole crop of cotton (Table 1). Plant height, dry matter production, monopodia/plant, opened bolls/plant and boll weight of cotton were higher in intercropping system. The cumulative effect of more and heavy bolls in intercropped cotton led to the increased pooled seed cotton yield by 0.2 tonne/ha over its sole stand. However, the differences in seed cotton yield (SCY) were not significantly marked. Groundnut as an intercrop with short and compact stature did not offer competition to cotton, and thus the growth condition of cotton in both sole and intercropping was identical. The positive impact of inclusion of groundnut as an intercrop owing to its ability of biological N fixation and reducing weed menace in between cotton rows favoured development of yield attributes in cotton, leading to higher SCY. These results are in close agreement with the findings of Waterworth (1994). Application of recommended dose of nitrogen (150 kg/ ha), irrespective of its source significantly enhanced number and weight of bolls over unfertilized crop. Further, cotton receiving N, irrespective of share of organic and inorganic sources produced similar number and weight of bolls. This difference in yield attributes was reflected in SCY. Application of 75% RDN + 25% FYM N gave the highest pooled SCY (3.2 tonnes/ ha), that was higher with 100% fertilizer N (3.1 tonnes/ ha). The SCY with 50% RDN + 50% FYM N was significantly lower when compared with 100% RDN and 75% RDN + 25% FYM N. Nitrogen fertilized cotton gave 0.97 tonne/ha of higher stalk yield when compared with unfertilized cotton. The stalk yields of N fertilized cotton, irrespective of its sources were similar except with 75% RDN + 25% FYM N which was significantly higher. 75% RDN + 25% FYM N increased the seed cotton (stalk) yield by 33.0% over 50% RDN + 50% FYM N, and 83.0% over control. It showed that under N limitation, seed cotton yield was more adversely affected than stalk yield. Substitution of 25% N through FYM did not adversely affect the cotton crop. On the contrary, the prolonged supply of N and other nutrients due to slow mineralization of FYM coupled with reduced losses of fertilizer N as it binds with FYM might have reduced the leaching losses. Thus supply of N matching with the crop needs led to development of more yield attributes. However, substitution of 50% fertilizer N through FYM proved counterproductive to some extent as this level of substitution drastically altered the N supply to the crop. The rate of mineralization of FYM failed to release the required N at critical periods of formation of yield attributes. This is in line with findings of Rathinakumari *et al.* (2004). The SCY and total N uptake were significantly influenced by N fertilization and also by extent of fertilizer N substitution with FYM. Application of 75% RDN + 25% FYM N recorded the highest total N uptake 226.5 kg/ha (Table 3). The N uptake in cotton with 100%RDN was at par with the above treatment. The same trend was observed with phosphorus and potassium uptake.

Groundnut

The performance of groundnut was drastically altered in intercropping with cotton when compared with its sole stand. This is evident from data on yield attributes and yield. Pods/ plant was adversely affected in intercropping. Intercropped groundnut, on an average, produced 33.0% less pods/plant of its sole crop (91.5). However, the extent of reduction in kernels/pod and 1000 kernel weight in intercropping was of lesser magnitude when compared to its sole stands. The cumulative effect of reduction in pods/ plant, kernels/pod and 1 000 kernel weight in intercropped groundnut led to its lower productivity (43.6%) when compared to its sole cropping (1.06 tonnes/ha). The poor performance of groundnut in intercropping was mainly attributed to lower plant population (45% base population in intercropping as compared to sole groundnut). Further, the shading effect of cotton (90 days after sowing onwards) and competition for resources, particularly water and nutrients also contributed to lower values of yield attributes and yield (Table 2). Among the three rows of groundnut in intercropped cotton, the contribution of centre row to the yield was the maximum. These results are in accordance with the findings of Waterworth (1994). Cotton receiving no N showed superior performance of intercropped groundnut in terms of pods/ plant, kernels/ pod and pod yield as compared with 75% RDN + 25% FYM N. Groundnut performance in fertilized treatments were at par. This could be attributed to the fact that poor performance of cotton in control treatment caused less shady conditions in intercropped groundnut leading to increased number of pod/ plant and kernels/pod, and consequently greater pod yields when compared to fertilized treatments. Similar results were also reported by Kambale *et al.* (2002). The N uptake followed the similar trend to that of pod yields (Table 3). Sole groundnut had significantly higher mean N uptake (115.4 kg/ha) than intercropped groundnut (46.7 kg/ha). The higher N uptake in sole groundnut could be ascribed to the fact that it received recommended dose of fertilizers (N, P), while intercropped groundnut survived on nutrients applied to base crop of cotton. Hence, intercropped groundnut faced competition for nutrients from cotton when compared to sole groundnut. N uptake was lower in intercropping because of less pods and biomass yield of groundnut. Cotton with no N and 50% RDN + 50% FYM N produced higher yield because of less shading effect by cotton and thus enabled groundnut to acquire more nutrients. Similar results were also reported by Meena *et al.* (2011).The mean N, P, K uptake in intercropped cotton was 79.4, 6.6, and 46.0 kg/ha higher than sole cotton (149.9, 16.3 and 80.0 kg/ ha) respectively, while sole groundnut recorded the least N, P and K uptake (115.4, 9.8 and 78.0 kg/ha, respectively) which might be attributed to cumulative effect of the highest biomass production and nutrients uptake under intercropping system.

Seed cotton equivalent yield

Cotton + groundnut system recorded significantly higher cotton equivalent yield (19.5%) over sole cotton (Table 2). Similar cotton yield in intercropping as that of sole cotton coupled with additional yield of groundnut pods (0.47 tonne/ ha) resulted in superior performance of intercropping system. The results are in agreement with those of Singh *et al*. (2011). 100% RDN increased seed cotton equivalent yield by 1.12 tonnes/ ha (56.5%) over unfertilized control. Substitution of 25% N through FYM has 6.2% (0.21 tonne/ha) higher seed cotton equivalent yield than 100% RDN. Further increase in substitution of RDN through FYM proved counterproductive. This is evident from the fact that seed cotton equivalent yield were reduced by 0.43 tonne/ ha (17.7%) over 100% RDN. This might be due to efficient utilization of resources and less competition between component crops.

Biological feasibility

Control treatment gave the highest LER, RNR and ATER, followed by 50% RDN + 50% through FYM (Table 2). The higher values could be due to better and efficient utilization of growth resources, resulting from temporal and spatial complementarity. Higher LER in control was due to higher productivity of groundnut owing to more availability of solar energy in poor canopy cotton crop, resulting in less competition among plant for natural resources. Aggressivity values indicated that cotton had positive values for all fertility levels while more negative for groundnut. This shows that groundnut was dominated by cotton under all fertility levels. Dominating nature of cotton was due to its tall stature, higher leaf area, resource exhaustiveness while it was the reverse for groundnut. The product of RCC should be more than one for the system to be advantageous. At all fertility levels, the product of coefficient was less than one indicating that intercropping system was not advantageous in terms of intercrop faced adverse effects of base crop like shading effect at reproductive stages of intercrop, resulted in stunted growth and less pod yield. While their association was beneficial because of spatial and temporal complementarity between both crops and also having the different rooting pattern and contrast nature to utilize natural resources efficiently. In cotton, the highest competition ratio was noticed at 75% RDN + 25% through FYM, followed by 100% RDN. In groundnut, the highest competition ratio was noted in control treatment, followed by 50% RDN + 50% through FYM. These findings are in accordance with the findings of Waterworth (1994).

Economic viability

Cotton + groundnut system on an average fetched ₹ 12 910 more net returns and thus has 0.54 more B: C ratio than sole cotton (Table 2). Sole groundnut proved uneconomical of the three cropping systems because of less than one IER (0.46). The higher seed cotton equivalent yield (0.5 tonne/ ha) coupled with the corresponding stover yield

Table 2 Competition functions and economics of cotton with groundnut intercropping system (mean data of 2006 and 2007)

Treatment	Land equivalent ratio (LER)	Aggressivity		Relative crowding co-efficient (RCC)			Competition ratio (CR)		Area- time equivalent ratio (ATER)	Relative net returns	Pooled seed cotton equivalent yield (tonnes/ha)	Net returns (₹/ha)	B:C ratio	Income equivalent ratio (IER)	Production efficiency (kg/ha/day)
		A_c	A_g	K_c	K_g	Product of K	CR_c	CR_g							
Cropping system															
Sole cotton											2.6	33,638	1.70	1.05	14.4
Sole groundnut											1.06	5,132	0.36	0.46	8.2
Cotton + groundnut (1:3)	1.56	3.82	–3.82	–32.63	0.27	–8.81	7.60	0.13	1.40	1.26	3.1	46,548	2.24	1.56	17.2
CD (*P*=0.05)											0.13				
Fertility level															
Control	1.72	3.74	–3.74	–27.44	0.36	–9.88	6.32	0.14	1.47	1.37	2.0	26,970	1.61	1.66	11.1
100% RDN	1.47	3.71	–3.71	–17.77	0.23	–4.08	7.97	0.13	1.33	1.18	3.0	48,445	2.58	1.53	16.7
75% RDN + 25% through FYM	1.48	3.89	–3.89	–48.50	0.21	–10.18	8.65	0.12	1.36	1.20	3.5	50,780	2.29	1.48	19.4
50% RDN + 50% through FYM	1.59	3.95	–3.95	–36.68	0.28	–10.27	7.44	0.14	1.42	1.28	2.8	34,887	1.38	1.56	15.5
CD (*P*=0.05)										0.19					

A_c and A_g, Aggressivity of cotton on groundnut and groundnut on cotton, respectively; K_c and K_g, RCC of cotton on groundnut and groundnut on cotton, respectively; CR_c and CR_g, CR of cotton on groundnut and groundnut on cotton respectively.
Prevailing minimum support prices of cotton and groundnut were @ ₹ 20 100 and ₹ 15 350/tonnes, respectively

Table 3 Effect of intercropping system on nutrient uptake and available soil N, P and K status (mean data of 2006 and 2007)

Treatment	Nutrient uptake by cotton (kg/ha)			Nutrient uptake by groundnut (kg/ha)			Nutrient uptake by cotton + groundnut (kg/ha)			Available nutrient (kg/ha) after harvest of crops		
	N	P	K	N	P	K	N	P	K	N	P	K
Cropping system												
Sole cotton	149.9	16.3	80.0				149.9	16.3	80.0	249.5	15.4	265.7
Sole groundnut				115.4	9.8	78.0	115.4	9.8	78.0	302.1	12.3	258.4
Cotton + groundnut (1:3)	182.5	19.3	93.4	46.7	3.6	32.5	229.2	22.9	125.9	340.7	12.6	255.9
CD (*P*=0.05)	NS	NS	NS	6.43	0.62	7.56	39.59	6.54	12.69	33.83	NS	NS
Fertility level												
Control	86.7	10.0	52.6	54.6	4.2	43.1	141.5	14.6	96.2	183.8	12.2	256.8
100% RDN	200.9	20.4	98.7	43.7	3.4	27.8	245.2	23.8	126.7	269.0	9.5	250.2
75% RDN +25% through FYM	226.5	24.0	109.5	39.0	3.1	23.4	265.8	27.5	132.6	307.2	12.8	258.6
50% RDN + 50% through FYM	150.0	17.5	86.1	49.5	7.7	35.2	200.3	25.2	121.5	343.2	14.4	262.8
CD (*P*=0.05)	48.67	4.82	20.86	8.74	0.82	9.68	55.99	6.32	13.57	46.76	2.38	5.32

coupled with minimal increases in cost of cultivation has resulted in higher net returns and B:C ratio in cotton + groundnut system. Application of 100% RDN through fertilizers enhanced mean net returns by ₹ 21 475 over control. Further application of N as 75% RDN + 25% through FYM enhanced net returns by ₹ 2335 over 100% RDN. Increasing the FYM to 50% reduced net returns by ₹ 13 559 over 100% RDN. The increase in yield with substitution of 25% RDN through FYM has more than offset the increased cost, thus having a net gain of income. The reduced yield (0.43 tonne/ ha) coupled with greater cost of FYM (₹ 400/ tonne) in 50% RDN + 50% through FYM has resulted in reduced net returns over 100% RDN. The highest B:C ratio was observed with 100% RDN followed by 75% RDN + 25% through FYM. Higher net returns with combined N source was due to higher seed cotton yield. The low B:C ratio with FYM application was owing to greater cost of FYM addition. Intercropped cotton recorded 16.3% higher production efficiency over sole cotton. Further application of N as 75% RDN + 25% through FYM enhanced production efficiency by 14.0% over 100% RDN. Among fertility levels, control treatment accounted maximum IER (1.66), indicating superiority of this treatment over others. This was due to increased proportion of net returns in relation to cost of cultivation. Similar results were also observed by Singh *et al*. (2011).

Post-harvest soil fertility status

Cotton + groundnut system maintained significantly higher available soil N over sole cotton in comparison to initial soil N status. By substitution of 50% RDN through FYM had the highest available soil N, P and K being at par over 25% RDN substitution through FYM. This treatment recorded significantly higher soil available N, P and K over 100% RDN. Control plots had the lowest available soil NPK. Cropping system did not significantly affect available P and K content of soil after harvest of cotton and groundnut over initial soil status. It was observed that there was significant reduction in available P content of soil with 100% RDN as compared to other treatments including control. Application of 50% RDN + 50% through FYM could improve the available P content in soil over control. This might be due to multidimensional role of FYM ranging from building-up of organic matter, improving soil aggregation, soil permeability and related physical properties to long lasting supply of several macro and micronutrients, besides improving the cation exchange capacity of soil (Behera *et al.* 2007). Increase in available NPK might be due to the direct addition of N through FYM to the available pool of the soil. It could also be attributed to greater multiplication of soil microbes which could convert organically bound N to inorganic form. The increase in available P might be due to decomposition of organic matter. But increase in available K might be ascribed to direct addition of K to available pool of the soil, besides the reduction in K-fixing and release of K due to the interaction of organic matter with clay.

Thus it can be concluded that intercropping of cotton with groundnut with substitution of 25% of N requirement through FYM is biologically and economically sustainable cropping system for agro-climatic conditions of northern India.

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REFERENCES

Ahlawat I P S, Gangaiah B and Ompal Singh. 2005. Irrigation requirement of gram *(Cicer arietinum*) + Indian mustard

(Brassica juncea) intercropping system. *The Indian Journal of Agricultural Sciences* **75** (1) : 23–6.

Behera U K, Sharma A R and Pandey H N. 2007. Sustaining productivity of wheat – soybean cropping system through integrated nutrient management practices on the Vertisols of central India. *Plant and Soil* **297**: 185–99.

FAO. 2007. Food and Agriculture Organization of the United Nations. *faostat.fao.org*.

ISAAA. 2008. International service for the acquisition of agri-biotech application. *www.isaaa.org*

Kambale M S, Kathmale D K, Najan B R and Gandkar P P. 2002. Effect of recycling of organic farm wastes on yield of groundnut *(Arachis hypogaea*). *Extended Summaries Vol. 1: 2nd International Agronomy Congress*, November 26–30, 2002, New Delhi.

Manjunath T M. 2004. Bt cotton in India: The technology wins as the controversy wanes. http://www.monsanto.co.uk/news/ukshowlib.html?wid=8478

Meena B P, Kumawat S M and Yadav R S. 2011. Effect of planting geometry and nitrogen management on groundnut *(Arachis hypogaea*) in loamy sand soil of Rajasthan. *The Indian Journal of Agricultural Sciences* **81** (1) : 86–8.

Rathinakumari S, Subbaravamma P and Nariji Reddy A. 2004. Response of cotton to farmyard manure in deep black cotton soils under rainfed conditions. *(in*) *National Symposium on Changing World Order-Cotton Research, Development and Policy in Context*. ANGRAU, Hyderabad, 10–12, August 2004.

Singh Raman Jeet, Ahalawat I P S, Gangaiah B. 2009. Direct and residual effects of nitrogen management in *Bt* cotton –wheat cropping system. *Indian Journal of Agronomy* **54** (4) : 401–8.

Singh Ummed, Singh S R, Saad A A, Khanday B A and Singh J K. 2011. Yield advantage, reciprosity functions and energy budgeting of lentil *(Lens culinaris*) + oat *(Avena sativa*) intercropping under varying row ratio and phosphorus management. *The Indian Journal of Agricultural Sciences* **81** (3) : 219–25.

Venugopalan M V, Sankaranarayanan K, Blaise D, Nalayini P, Prahraj C S, Gangaiah B. 2009. Bt cotton in India and its agronomic requirements. *Indian Journal of Agronomy* **54** (4) : 343–60.

Waterworth J V. 1994. Intercropping cotton and groundnut in low and high rainfall areas in Eastern Zambia. *Experimental Agriculture* **30** (4) : 461–5.